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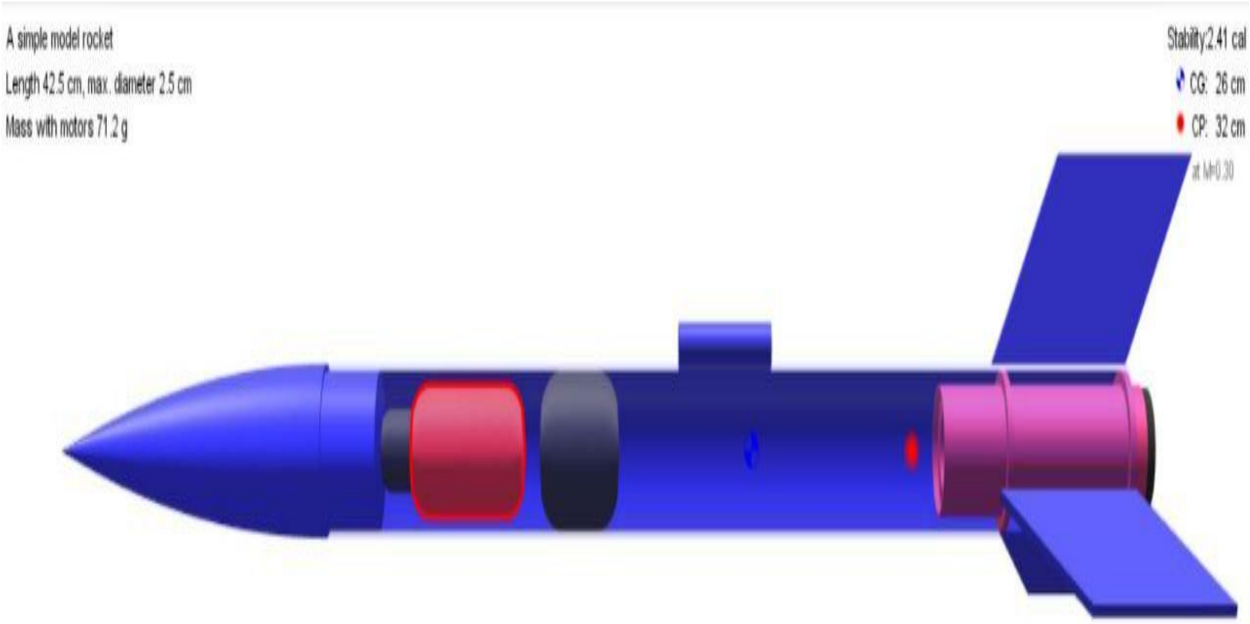

TEAM TCD

LET IT GO(WITHOUT A BANG!)

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Contents

Project title: Let it go (Without a bang)/Magnetic Detachment Mechanism(MDM)

Intorduction

Space missions need separation devices that are both light weight and low shock in mission related functions such as landing. In the past week, our group has been tirelessly working on developing a completely new non-pyrotechnic separation device from scratch. The current pyrotechnic designs result in high landing costs due to the high amount of shock they release. This is a severely important aspect in separation devices of small satellites as these shocks can directly affect their sensors and magnets functionality. The MDM (Magnetic Detachment mechanism) holds all the features of the earlier model (the light ands) which means it still has the earlier operational goal of reset ability, low shock, high-speed release, ease of use separation nut.

The TCD team has wanted to challenge themselves even more to bring this model to another level by adding a few other design aspects. One which was to extend the withstand able energy to 100 degrees Celsius.

The second aspect of this design is its weight, the MDM weight to about 1kg.This makes them compatible with tiny satellites such as picosats. This was a key issue with the existing models as we noted above.

The MDM come up with a surface area of 15* 2 cm, which is perfect size as it allows other more crucial mechanical devices to fill out the empty surface area. Also, it is assumed based on our theoretical calculations that this mechanism comes up with preload capabilities like the pre-existing devices.

With the current high demand in assembling smaller satellites neither the pyro-technic separation devices nor would the current large scale Light bands answer this need.

The applications added to the MDM can someday make it a candidate for replacement with current low shock Light bands.

Lastly, even though the attention of this project mainly was on release of parachute, we believe that this mechanism has the capacity of eventually be modified to suit other applications where non-pyrotechnics are used, such as rocket stage separation and fairing.

Mechanism

Magnetic detachment mechanism (MDM) hugely relies on the demagnetization property of the magnets. It is a simple mechanism with quite a complex science behind it. The magnets are placed in the lid to keep the mechanism enclosed until the parachutes are to be released. To open the lids, the heating system in the device is brought up to 100°C. At this temperature, the magnets demagnetize, and the lids are opened for the parachute.

This device uses two semi-circle shapes attracted to each other with magnetic force. This shape forms the lid and this lid stays enclosed until enough heat is given for it to reach its max working temperature and magnets are opened for the parachute to be released.

The lids contain two ring shapes that go around a bar that is connected to the cylinder. This connection acts as a hinge, where it allows the lids to rotate freely. This system allows the lid to open or close. When the parachute is released, this allows the lids to stay in contact to avoid and free debris to escape to the space.

A neodymium magnet is used to attract the lids to each other. This magnetic force allows the lid to stay closed and intact to the cylinder. The neodymium magnet used has the suffix "M", which means that it has a maximum working temperature of 100°C. Neodymium magnets are one of the strongest types of magnets that can be found on our planet. The strong magnetic force allows the MDM to have safe and successful travel.

A heating device is used to increase or decrease the temperature in the actuator. The heating system is placed right below the main opening, when it's the time for the separation, the temperature is brought up to 100°C. This demagnetizes the magnets, and the lids open up as nothing is holding them together. The parachute is released, and the mission is completed with no free debris thrown in the space.

This device is also reusable as the magnets still haven't reached its Curie temperature of 320°C, it can be remagnetized and used again. This also makes this device a cost-efficient product.

Validity

This separation mechanism would work, because;

· Aluminium would be the main material used for the shape of the cylinder and this certain material can withstand the given heat range of -50C to +80C.

· Neodymium magnets would be used to hold the two parts of the lid attached. The type of neodymium used would be of “M” suffix with a maximum working temperature of 100C. The heating system would be used to bring the temperature up to 100C. At this point, the magnet would demagnetize, and the lid would separate from each other letting the parachute fly up. The magnets work perfectly in space as it is in a vacuum, so this would be of no problem. The magnet would also survive the given heat range. As the magnets don’t reach up to the Curie level of temperature, they can be remagnetized and used again in future experiments.

· The two semi-circle-shaped lids would be connected to the cylinder with a specially designed hinge where it can rotate freely. This attachment allows the lid parts to stay connected to the cylinder shape after the separation process is applied. This would make sure that there is no net debris left out in the space.

All of the above conditions would suggest that this mechanism would work.

Calculations

	Aluminum	Platinum	Copper	Tin
Density (kg/m^3)	2700	21450	8940	7310
Specific heat capacity (kJ/kg*K)	887	150	385	226
Cost ($/kg)	2.9	31250.0	9.25	34

Having searched for different materials that could be used for creating our device, a table from above was made, showing 3 crucial properties of them.

Four of these materials are suitable for our machine, since priority for used material for us was the weight (<1 kg). All densities from above for a volume that we have (approximately 17 cm^3) result in suitable values of masses.

Although Aluminum is the most common material used for spacecraft, its specific heat capacity is large compared to other metals. This means that using Aluminum will make the machine lose its heat very fast.

Platinum is a very good material for our creation. On the other hand, it is extremely expensive.

Copper and Tin are more of an average choices. They might be well for usage, still having downsides.

Equations

$$Drag = \frac{1}{2} C_d \rho v^2 A$$

$$D = \frac{1}{2} * 0.82 * 1.225 * 3000^2 * (0.01^2 * \pi) \approx 1420N$$

$$Q_{air} = cm\Delta t$$

$$Q_{air} = 1006 * (1.225 * 0.15 * \pi * 0.009^2) * \big(80 - (-50)\big) \approx 0.006J$$

$$t = \frac{Q}{P}$$

$$t = \frac{0.006J}{20W} = 0.3055$$

$$m = \rho V$$

$$m = 2700 * \big(0.15 * \pi * (0.01^2 - 0.009^2)\big) \approx 0.024kg = 24g$$

Why would our machine work?

Our machine is a cylinder (1cm radius, 15cm height) made of Aluminium, containing air inside, with two magnets on top of it. It is, again, small, but also light and commonly used in spacecraft.

$$m = \rho V$$

$$m = 2700 * \left(0.15 * \pi * (0.01^2 - 0.009^2)\right) \approx 0.024kg = 24g$$

Mass of parachute it not included

When our machine is attached to a rocket **<u>HOW IS IT ATTACHED???</u>** And rocket has its velocity, the machine would face some Drag force. Its magnitude can be easily calculated using a special formula for drag (if the top part heads the direction of a flight):

$$Drag = \frac{1}{2} C_d \rho v^2 A$$

$$D = \frac{1}{2} * 0.82 * 1.225 * 3000^2 * (0.01^2 * \pi) \approx 1420N$$

Since we have a small cylinder with not a large amount of air in it, it will be easy to heat it up to 100 degrees Celsius (whether from -50 or 30):

$$Q_{air} = c\rho V \Delta t$$

$$Q_{air} = 1006 * 1.225 * (0.15 * \pi * 0.009^2) * \left(80 - (-50)\right) \approx 0.006J$$

Assuming that the largest power source we have is 20W:

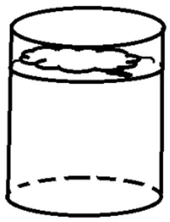
$$t = \frac{Q}{P}$$

$$t = \frac{0.006J}{20W} = 0.3055$$

We heat the magnets up for a demagnetisation effect to kick in. This effect will let us open the lid and let the parachute out.

All effects that work for magnets on Earth, also work in space. This means that when magnets demagnetise, they can be remagnetised again using another strong magnet. This means that <u>our machine is reusable</u>.

Discussion



What if we have a parachute between two lids?

- No conductivity
- Lids won’t unite
- When magnets “bye-bye” top lid flies away and parachute is released

Finances and Materials

Dimensions à Cylinder

Length:15cm x Diameter:2 cm

Radius: 1cm

Thickness: 1mm

Aluminium Density: 2.7 g/cm³

Aluminium 7075 Cost: $2.9/kg à Weight of structure: 0.025kg

Cost for structure: $0.072

Neodymium magnet $9.70 Heater $9.12

Net Cost: $18.89

Validity of Demanganization of Neodymium magnet

At Curie Temperature, 350°C, the magnet loses magnetism permanently, but at 80° temporary magnetism is lost.

References

1.

Christiansen, Scott, Scott Tibbitts, and David Dowen. n.d. “AST ACTING NON-

PYROTECHNIC 10kN

SEPARATION NUT.” *AST ACTING NON-PYROTECHNIC 10kN SEPARATION NUT*, 4.

https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=2108&context=smallsat.

2.

Peffer, Andrew. n.d. “Development and Transition of Low-Shock Spacecraft Release Devices

for Small

Satellites.” *14th Annual/USU Conference on Small Satellites*.

https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=2108&context=smallsat.

3.

H. Liu, H. Lin, Z. Q. Zhu, M. Huang and P. Jin, "Permanent Magnet Remagnetizing Physics of a Variable Flux Memory Motor," in *IEEE Transactions on Magnetics*, vol. 46, no. 6, pp. 1679-1682, June 2010, doi: 10.1109/TMAG.2010.2044638.

4.

H. Xiong, J. Zhang, M. W. Degner, C. Rong, F. Liang and W. Li, "Permanent-Magnet Demagnetization Design and Validation," in *IEEE Transactions on Industry Applications*, vol. 52, no. 4, pp. 2961-2970, July-Aug. 2016, doi: 10.1109/TIA.2016.2544739.

5.

Schwöbel, J., Fu, Y., Brede, J. *et al.* Real-space observation of spin-split molecular orbitals of adsorbed single-molecule magnets. *Nat Commun* **3,** 953 (2012). https://doi.org/10.1038/ncomms1953

References for the materials:

6.

https://www.first4magnets.com/tech-centre-i61/frequently-asked-questions-i69

7.

https://www.kjmagnetics.com/blog.asp?p=temperature-and-neodymium-magnets

8.

https://www.alibaba.com/showroom/aluminium-7075-price-per-kg.html